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HUBBLE SPACE TELESCOPE

LEVEL 1 REQUIREMENTS

FOR THE OPERATIONAL PHASE

OF THE HUBBLE SPACE TELESCOPE PROGRAM

This Level 1 requirements document for the Hubble Space Telescope is a merging of requirements as defined in the approved 1983-85 and the 1989 Level 1 Requirements documents, as amended by approved waivers and Critical Decision Items (CDI's). The intent of this formal release is to present the complete Level 1 requirements in a single integrated document. As such, it supersedes and replaces all previous Level 1 requirements documents.

Office of Space Science

Astrophysics Division

National Aeronautics and Space Administration
NASA Headquarters
Washington, DC

February 29, 1996

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LEVEL 1 REQUIREMENTS
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HUBBLE SPACE TELESCOPE
LEVEL 1 REQUIREMENTS
FOR THE OPERATIONAL PHASE

1. SCOPE

This document combines and updates the original Hubble Space Telescope (HST) Level I Requirements document dated December 23, 1983, the amendment dated October 29, 1985, and the Level 1 Requirements operational phase augmentation document dated May 17, 1989. Approved waivers and approved Critical Decision Items (CDI's) have been incorporated as required. The requirements herein cover the operational phase of the HST program. The performance requirements provided in this document represent the minimum performance levels to be used in assessing the need for on-orbit servicing or upgrade and for ground system modifications.

The mission of the HST Project is to provide a space observatory for use by the international astronomy community to increase the sensitivity and resolving power and extend the spectral range of astronomical observations decisively beyond those achievable from earth observatories.

The normal operations and condition of the HST will be maintained by NASA, including the command, control, and communications system. Within broad policy generated by NASA, the HST science program will be managed by the Space Telescope Science Institute (STScI) to maximize the scientific usefulness of the observatory and to bring the user community into direct contact with and control of the science that is done.

The European Space Agency (ESA) has provided two sets of solar arrays and one scientific instrument (the Faint Object Camera) for the Hubble Space Telescope and personnel for the STScI. In return, scientists from ESA member nations are guaranteed at least 15 percent of the HST observing time on the average through May 2001. ESA participation is defined in a Memorandum of Understanding.

1.1 Control

This document shall be controlled at Level I by NASA Headquarters, Office of Space Science (OSS), which carries the primary responsibility for fulfillment of these requirements.

2. OVERALL PROGRAM REQUIREMENTS

The goal of the HST program during the operational phase is to maximize the scientific productivity of the Observatory. To meet this goal, NASA shall operate, maintain and enhance the HST spacecraft and supporting ground

systems while the Space Telescope Science Institute (STScI), in accordance with NASA policy guidance and oversight, shall conduct the HST science program.

2.1 Operational Life [1]

A high level of scientific productivity, using acquisition methods and strategies in conjunction with instrumentation selected through peer review, shall be maintained to the extent possible, and/or practical, for 15 years, or longer.[2] The measures to be taken to achieve this will include:

a. operational work-arounds such as procedural and software changes,
b. orbital replacement of malfunctioning spacecraft equipment,
c. orbital replacement of scientific instruments,
d. orbital replacement of limited-life equipments or units, at the appropriate mission life points,
e. development of Space Support Equipment (SSE) to support maintenance missions,
f. maintenance and upgrade of the supporting ground system, and
g. reboost as required to maintain a satisfactory orbital altitude.

2.2 Servicing Mission Authorization

The execution of all servicing missions requires approval by the NASA Administrator.

2.3 Scientific Capabilities

A scientific measurement capability is provided through a complement of up to four axial scientific instruments, one radial scientific instrument, and three Fine Guidance Sensors.[3] This capability shall be maintained and enhanced through the acquisition and on-orbit installation of replacement scientific instruments and Fine Guidance Sensors, and the maintenance and modification of the supporting ground system. The HST shall be able to accommodate a cryogenically-cooled infrared SI, including provision for the removal of evaporated cryogen from the aft shroud.

2.4 Space Transportation

The Space Shuttle shall provide the basic transportation for all phases of the HST program including deployment, on-orbit servicing, and reboost or return to earth.

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1 Per CDI-049.

2 Per CDI 054.

3 GSFC Waiver #11 points out that the first servicing mission installation of the corrective optics package COSTAR left HST one short of the five SI's called for in the original wording. The wording of this sentence has been modified to make it more flexible in terms of instrument complement.

2.5 Communications

All normal forward and return link data transmission shall be via the NASA Communications Network (NASCOM) and the Space Network (SN). In situations where there is an outage of the normal communication service, the remaining or replacement elements of the Deep Space Network (DSN) 26 meter subnet or the Goddard Space Flight Tracking and Data Network (GSTDN) shall provide tracking, command, and engineering telemetry for health and safety communications support.

2.6 Mission Termination

At the completion of the useful operational life of the HST, as determined by NASA Headquarters, the HST shall be either placed in a long-term stable orbit or safely deorbited.

3. OBSERVATORY PERFORMANCE

The purpose of this section is to define the minimum acceptable performance capabilities for the Observatory. These shall serve as criteria for planning and initiating orbital servicing activities. It is expected that some flight subsystems will degrade with time, e.g., the HST exterior thermal coatings, which cannot be refurbished or replaced and whose degradation cannot be circumvented by ground system work-arounds.

3.1 Image Quality

The optical system shall consist of a f/24 Ritchey-Chretien telescope with a 2.4-meter diameter primary mirror and corrective optics. The optical image, including effects of optical-wave front error, pointing stability, and scientific instrument to OTA alignment, should satisfy the following on-axis requirements at 6328 Angstroms and be a design goal at ultraviolet wavelengths: 70%[4] of the total energy of a stellar image must be contained within a radius of 0.10 seconds of arc; the resolution of the image using the Rayleigh criterion for contrast shall be at least 0.10 seconds of arc; and the full-width half-intensity diameter of the image shall be no more than 0.10 seconds of arc. After correction for astigmatism, these specifications shall apply to the image quality over the entire usable HST field.

The HST shall be capable of collecting and imaging radiant energy in a broad spectral band from 1216 Angstroms to 10 micrometers. Specifically, the OTA optical throughput, which includes the combined reflectivity of both the primary

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[4] GSFC Waiver #2 requested the 70% figure to be changed to 60% at 6328Å and 35% at 1216 Å. However, the original Level 1 requirement was met or exceeded following 1993 servicing mission, so the requirement has not been modified.

and secondary mirrors and the central obscuration effect, shall be no less than 38 percent at 1216 Angstroms and 55 percent at 6328 Angstroms.[5]

The overall system must be capable of measuring unresolved objects appreciably fainter than those accessible from the ground; i.e., at least 27 m_V with a signal-to-noise ratio of 10 in 4 hours of observing time.[6]

The overall system must be capable of measuring extended sources of surface brightness 25 m_V per square seconds of arc with a signal-to-noise ratio of 10 in 10 hours, with a resolution of at least 0.25 seconds of arc.[7]

3.1.1 Image Stability

The image jitter due to all causes shall be less than 0.012 arcsec R.M.S. over a period of 24 hours. The optical image quality, as defined in 3.1. shall be simultaneously maintained at the apertures of up to four axial scientific instruments[8], one radial scientific instrument, and three Fine Guidance Sensors for elapsed periods of 24 hours allowing up to 4 hours for thermal stabilization after thermally worst-case slews.

3.1.2 Target Positioning [9]

The HST shall contribute an error no greater than 0.03 arc seconds during the acquisition and positioning of a fixed or moving target within any instrument aperture.

3.1.3 Guide Star Acquisition & Tracking [10]

The HST must be able to acquire and track on guide stars in at least 75% of randomly selected targets located at the galactic poles when using the stellar statistics of "Guide Star Probabilities", NASA Contractor Report 3374, January 1981.

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5 GSFC Waiver #19 requested waiver based on reduced throughput that would result with incorporation of COSTAR. However, the original Level 1 requirement was met or exceeded following 1993 servicing mission, so the requirement has not been modified.

6 GSFC Waiver #3 wanted to reduce this requirement. The original Level 1 requirement was met or exceeded following 1993 servicing mission, so the requirement has not been modified.

7 GSFC Waiver #4 requested a 10% reduction in the requirement for extended object sensitivity. The original Level 1 requirement was met or exceeded following 1993 servicing mission, so the requirement has not been modified.

8 GSFC Waiver #11 points out that the first servicing mission installation of the corrective optics package COSTAR left HST one short of the five SI's called for in the original wording. The wording of this sentence has been modified to make it more flexible in terms of instrument complement.

9 Per CDI-057.

10 Per CDI-058.

3.1.4 Solar System Object Tracking [11]

Tracking errors for moving targets shall remain less than 0.03 arcsec. r.m.s., for tracking rates less than 0.02 arcsec/sec, and less than 0.04 arcsec, r.m.s., for tracking rates between 0.02 and 0.20 arcsec/sec, over 3 arcmin apparent displacement.

3.1.5 Stray Light Performance

The scattered light surface brightness must be less than 23 m_V per square seconds of arc except within 50 degrees of arc of the sun or 30 degrees of arc of the moon or 90 degrees of arc of the bright earth limb.[12]

3.2 Scientific Observational Capabilities

The scientific productivity of the HST requires that certain core observational capabilities be maintained throughout its operational lifetime. Loss of any of these capabilities shall justify instrument replacement at the earliest planned servicing mission.

3.2.1 Core observational Capabilities

Allocation of time and details of observing programs are based on scientific merit. In the long term, a stable observational capability shall be provided to enable the following:

a. Visible photometric imaging at high spatial resolution for science and target acquisition support.
b. Ultraviolet spectrophotometry at medium to high spectral and spatial resolution.
c. Near infrared spectrophotometry (> 1 micron) and imaging with high resolution. This capability is to be available for at least five years of HST lifetime, and should be instituted as soon as possible after launch.[13]

High spatial resolution is intended to mean roughly 2 samples per cycle at a 50% value of the Optical Telescope modulation transfer function. Medium and high spectral resolutions are intended to mean 1000 and 30,000, respectively. The minimum fields of view for the UV/visible and IR imaging shall be approximately 90 and 10 arcsec, respectively. Performance degradation below any of the levels stipulated - but not total loss - does not constitute justification for immediate instrument replacement, but shall be a factor in prioritizing replacement in service mission planning. The capability of conducting parallel observations, i.e., concurrent operation of any two science instruments on a non-interference basis, is a general core capability.

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[11] CDI-063 waived this requirement for launch, but required implementation by March 1991. In 1993, GSFC requested a further waiver, which was denied.

[12] Revised from 80 degrees to 90 degrees per CDI-055.

[13] Per CDI-066.

3.2.2 Additional Observational Capabilities

In addition to the core capabilities, a versatile observational capability shall be maintained to support, at any time, at least several of the following:

a Wide field of view (approx. 2 arcmin) visible imaging
b. Imaging at UV wavelengths
c. Faint object (approx. $m_v = 20.5$) visible spectroscopy at high spatial resolution
d Faint object UV spectroscopy
e. Very high resolution (approx. 10^5) UV spectroscopy
f. High speed (approx. 20 microsec) photometry.

3.3 Spacecraft Subsystems Performance

In general, unacceptable subsystem performance is that which compromises the observational capabilities specified in Section 3.2 or results in operational impacts which degrade science productivity. Specific requirements, which are particularly relevant to the maintenance of adequate support for science mission operations, follow.

3.3.1 Power [14]

The electrical power system shall provide adequate energy to maintain the scientific operational capabilities stated in paragraphs 3.2 and 3.2.1. In addition, the batteries shall maintain sufficient storage capability to enter safemode or gravity gradient mode (164 amp-hours). A servicing mission will be required prior to the time that the battery storage capability is projected to be less than 164 amp-hours or the solar array capability is projected to be less than that required to maintain scientific operational capabilities in paragraphs 3.2 and 3.2.1.

3.3.2 On-Board Data Storage

The flight system shall provide at least 100 Mbytes of science and engineering data storage.

3.3.3 Data Quality

The system shall provide a bit error rate not worse than 2.5×10^{-5} without Reed-Solomon encoding for all telemetry and 1×10^{-7} for end-to-end data flow for all data processed by the SI C&DH with Reed-Solomon encoding.

3.3.4 Time/Frequency

The system shall provide a clock signal to the science instruments with a 1 microsecond resolution relatable to Universal Time Code (UTC) to within 10 milliseconds. Frequency stability of the on-board frequency signal shall be at least $1X10^{-9}$ over 24 hours.

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14 Per CDI-053.

3.3.5 Data Management

The on-board system shall manage and communicate a long term average of 300 Mbytes of science data per day. It shall be capable of supporting approximately a twofold growth in this average data volume due to advanced instrument requirements.

4. GROUND SYSTEM REQUIREMENTS

The ground system required to support the HST program shall support Observatory and science management, the former performed by the Goddard Space Flight Center (GSFC) and the latter, under contract to GSFC, by the Space Telescope Science Institute (STScI).

4.1 General Functional Capabilities

The ground system shall provide the following general routine functional capabilities in support of mission operations:

a. Spacecraft and scientific instrument command and control.
b. Performance monitoring and engineering trend analysis.
c. Science and mission planning and scheduling, including parallel science data acquisition and parallel event scheduling.
d. Capture and processing of engineering and science data.
e. Science data analysis and general observer selection and support.
f. Archiving and distribution of science data and archival research support.
g. Support for spacecraft subsystem and science instrument maintenance, replacement and refurbishment.
h. Orbit and attitude data collection and processing.

4.2 Observatory Operations

The ground system shall be capable of supporting HST operations on a continuous basis. Availability for all mission critical facilities shall be at least 99.8% with a mean time to repair of less than 1 hour. The availability for off-line support systems shall be greater than 97.5% with a mean time-to repair of 8 hours. Routine maintenance shall be performed without disruption of flight operations support. The observatory operations project organization shall ensure that sufficient and appropriate hardware equipments and software programmers-developers and key hardware and software maintenance skills are available to support expected life-cycle activities, including the incorporation of efficiency and capabilities enhancements and upgrades and problems resolution.

4.2.1 On Line Operations

The following on-line operational capabilities, normally used to support real-time transactions, shall be provided: [15]

a. Generation, uplink, and logging of command loads and real-time commands.
b. Monitoring of all flight systems and science instruments in order to assure their health, safety, and data quality.
c. Generation and uplink of commands to adjust pointing and maintain tracking.
d. Attitude determination and sensor calibration in support of pointing control.
e. Monitoring and recording of the performance, runtime, and any anomalies in the flight and ground systems.

4.2.2 Planning and Scheduling

The ground system shall provide the following capabilities:

a Planning and scheduling, accounting for all constraints, in order to maximize efficient use of the Observatory. The goal is to achieve an annual average of 35% on-target time (OTT). OTT is defined to be the period which begins with the initiation of the Fine Guidance Sensor (FGS) acquisition process and ends with the release of the telescope pointing control each orbit (e.g., the HST is released to slew to the next target). In achieving this 35% goal, the intent is to minimize the amount of "on target' time spent for acquisition while maximizing the actual amount of target exposure time. If an observation can be accomplished on gyro control only, then OTT begins with commencement of science data collection or with any instrument-peculiar target acquisition procedures (e.g., shutter open) and ends with release of spacecraft pointing control each orbit.
b. Planning maneuvers and housekeeping activities to maintain the amount of dark time available for scientific observing at or above 20 minutes per orbit averaged over the precession cycle.
c. Timeline re-planning and scheduling for observing targets of opportunity within 24 hours of authorization.
d. Concurrent operation of two scientific instruments (parallel science) plus the use of a Fine Guidance Sensor for astrometry. [16]
e. Preparation of schedules and command loads for 24 clock-time hours of HST operation, including scheduling of parallel activities, in less than 12 working

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15 *Interactive selection and execution of alternative preplanned mission sequences (referred to as branching) for up to 20% of the total activity"* was formally waived via CDI-062 and GSFC Waiver #16.

16 Per CDI-059, waived for launch but to be implemented by March '91.

hours as a goal, and including the ability to reschedule 5% of these activities in response to mission needs.[17]

f. Maintaining reference materials and procedures to enable acquisition, tracking and observation of moving targets as per Section 3.1.4.

4.2.3 Servicing Mission Planning

The ground system, to support planning for servicing missions, shall provide reliability forecasting, mission simulations, mission operations and post-mission data processing and analysis.

4.2.4 Simulation and Test

The capability shall be provided to simulate the operation of the HST to support building or modifying hardware and software over the full life cycle of HST, test operational procedures and commands, assist in fault diagnostics, verify compliance of new subsystems against interfaces, and train new operators. The system shall be capable of testing new or revised flight software before installation without undue disturbance of ongoing normal orbital operations.

4.3 Data Acquisition

The ground system shall maintain and upgrade its data capture and processing throughput capability commensurate with advanced science instrument requirements.

4.3.1 Data Rates

The ground system shall be capable of simultaneously receiving data at rates of 1.024 Mbps and 32 or 4 or 0.5 Kbps.

4.3.2 Data Volume

The ground system shall be capable of capturing a peak maximum data volume of 900 Mbytes in a 24 hour period and of processing, on a long term average, 300 Mbytes daily for transmission to the STScI within 24 hours after receipt.

4.3.3 Data Storage

The ground system shall provide a minimum of 30 days of fail-safe storage of captured (unedited) data.

4.3.4 Data Dissemination

After a one year proprietary period, HST data shall be made accessible to the general scientific community. Archived data shall be periodically transferred to the HST European Coordination Facility and other facilities as authorized by the Associate Administrator, Office of Space Science.

4.4 Science Operations

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[17] Per CDI-061-R1.

The STScI has been established for the purpose of conducting and managing the science operations of the HST program. Its primary functions include:

a. Establishment of science program guidelines.
b. Selection of HST general observers and archival researchers, providing them technical assistance with their research programs, and managing grants to selected U.S. general observers.
c. Developing operational procedures and science observing schedules, including parallel science and parallel events scheduling.
d. Providing applications utilities and calibration data for analysis of HST data.
e. Processing, archiving and publicizing HST science data and results.
f. Evaluating Observatory and scientific instrument performance.
g. Maintaining the Guide Star Selection System.

4.4.1 Research Management

The ground system shall provide for the management and selection of research proposals, tracking associated resource requirements, and maintaining resulting products of the research throughout the life of the program.

4.4.2 Observing Support [18]

The ground system shall have the capability to support two general observers concurrently in the conduct of their observing programs involving such functional areas as target acquisition, acquisition verification, and quick-look data analysis.

4.4.3 Science Data Processing and Products

Calibrated standard data products shall be available to observers within five days of their acquisition. Uncalibrated data in SOGS format[19] shall be available to observers 24 hours after receipt by the STScI. Calibration algorithms, tables, and files shall be made available to authorized observers within thirty days of the request. Transportable versions of the data analysis software shall be maintained for use by observers who have access to compatible computers.

4.4.4 Data Archive

The capability shall be provided to archive, search and retrieve all the edited and calibrated science and related engineering data. The system shall support the access and distribution needs of up to 1000 archival researchers per year. A minimum of 3 years of current data shall be maintained on-line to facilitate automatic real-time interactive access. The remainder shall be permanently archived and retrievable, within a reasonable time, on request ("reasonable" defined as seconds to minutes if requested by an online user, and 1-2 weeks if by mail). The system shall accommodate both local and remote users via electronic

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18 GSFC Waiver #18 eliminated branching as a requirement.

19 Per CDI-064.

access, restrict access to only authorized users, and prevent against inadvertent loss or destruction of data, accidental or malicious.

5. SERVICING SUPPORT REQUIREMENTS

Over the operational lifetime of the HST, a capability must be maintained for on-orbit servicing in order to restore, wherever possible, original levels of performance and to enhance the science capability. Assuring this involves the timely development of replacement scientific instruments; Space Shuttle Program support; servicing mission planning; timely availability of Orbital Replaceable Units (ORUs); the development and maintenance of supporting test equipment, ORU delivery systems, spare components, and the Space Support Equipment (SSE); and a ground logistics system. Two classes of missions may be needed: Planned Service Missions (PSM) and Contingency Service Missions (CSM). Although both types require planning, the CSM launch preparation is triggered by a critical event, whereas the PSM occurs on a schedule related to forecasted maintenance need. A PSM is used to restore or upgrade the Observatory and scientific instrument performance (cf. Section 3.0). It is also used to reboost the spacecraft. The CSM corrects a failure which leaves a single point failure mode in a mission critical subsystem. A CSM may also be utilized to reboost the Observatory.

The program infrastructure shall maintain the capability to return the HST from orbit. The capability to return the HST from orbit shall not be maintained for every HST servicing mission, but instead will be provided only if so specified in the mission call-up instructions. That is, the hardware, software, procedures, etc., necessary for returning the HST from orbit shall be developed, verified, etc., on a schedule that permits the recovery of the HST by the Space Shuttle from orbit on any mission so desired, provided that recovery capability is specifically ordered up prior to mission initiation. Specific hardware capability does not, however, have to be planned for nor carried on every servicing mission, thus optimizing the use of the Space Shuttle lift capability to better support HST servicing missions where there is no identified imminent need for returning the HST.

5.1 Initiation Criteria

The decision to perform a servicing mission will be made by the Administrator in response to an Office of Space Science request. The request for a CSM will be initiated as soon as a justifying condition or pending condition is established. The need and requirements for a PSM shall be reviewed at least every six months and, under normal circumstances, confirmed at least 18 months prior to the scheduled launch.

A CSM will be requested whenever there is a loss of an ORU(s) which leaves the HST with a potential single point mission failure. A mission failure condition is

one in which the Observatory is no longer in communication with the ground or commandable, cannot be safely retrieved for servicing or reboost, is unable to support any science operations, or has lost the scientific payload. Potential failure of any one of the five major subsystems - power, thermal, pointing control, command and data handling, communications - is justification for initiating the CSM process.

The criteria considered in planning and requesting a PSM are the forecast of:

a. Orbital decay to an altitude such that science operations become constrained or mission duration is imperiled.
b. Loss of core observational capability as specified in Section 3.2.1
c. Subsystem performance degradation below levels specified in Section 3.
d Availability of advanced instruments.

Activities supporting conduct of a CSM will require major mobilization of effort across NASA in order to effect rapid repair of the HST. The basic purpose or such a call-up will of course be to repair the HST before it sustains further failure which could then result in irreversible damage to or loss of the Observatory. For planning purposes, the maximum allowable Space Shuttle response time - that is, time from call-up of the CSM by the Administrator to achieving launch readiness status - is assumed to be no greater than 12 months.

If resources and the situation allow, routine servicing activities and/or replacement of scientific instruments may be accomplished during a CSM.

5.2 Planning Support

The servicing support system shall:

a Maintain a long term schedule of servicing missions including best estimate of launch dates, the most likely complements of subsystems and scientific instruments, and associated procurement schedules and activities.
b. Provide a reliability model of the HST, updated periodically with flight data, for use in decision support and logistics management.
c. Account for all ORUs through a logistics data system covering reliability parameters, inventory status, and EVA timeline activities and tool requirements.
d Maintain trend analyses on sub-system performance, orbital decay and relevant geophysical models.

5.3 ORU Requirements

An inventory of critical Orbital Replaceable Units (ORUs) shall be provisioned and maintained to ensure support of a CSM call-up at any time. The inventory shall also include those ORUs which need to be replaced on PSMs based on current forecasts of need dates. To the extent the budget permits, an inventory of

desirable ORU changeouts, i.e., those which will result in enhancements, shall also be supported.

5.4 Orbital Replacement Instrument Requirements

In order to meet the scientific performance requirements established in Section 3.2 or to upgrade HST science return, additional scientific instruments will be acquired for installation on PSMs. These Orbital Replacement Instruments (ORIs) shall:

a Be fully compatible with the flight and ground data management and communication systems, as they currently exist or are expected to be upgraded.
b. Meet operational phase thermal, mechanical and electrical interface specifications.
c. Have as a design goal an operational lifetime of at least 5 years.
d. Use, to the maximum extent practicable, on-orbit replaceable subsystems.

Algorithms shall be provided along with the ORIs to permit on- orbit support and instrument-unique ground data processing.

5.5 Space Support Equipment

A baseline set of reconfigurable Space Support Equipment (SSE) shall be maintained to support servicing missions. This baseline includes:

a. The Flight Support System (FSS) to provide the mechanical and electrical interface between HST and the Space Shuttle.
b. Orbital Replacement Unit Carrier(s) to provide mounting, power, environmental protection and load isolation for the ORUs and ORIs.
c. EVA crew aids and tools.

On a single mission, the capability shall exist to carry into orbit a full set of replacement batteries, a set of solar arrays, at least one radial and one axial module, and multiple ORUs as required. The actual servicing mission equipment mix for a given mission will be determined by Observatory performance and trend analyses, space support equipment considerations, available EVA capability, Space Shuttle performance capabilities, and other considerations determined relevant at the time.

5.6 Technical Information Management

An automated information management system shall be maintained which provides:

a Management and resource control data.
b. Technical design and test data.

6. SAFETY AND EQUIPMENT RELIABILITY

6.1 Crew Safety

The design of the SSE, ORUs and ORIs shall assure that the Space Shuttle Orbiter or crew safety shall not be compromised at any time under either normal or contingency modes of operation. These modes include all phases of mission activity, i.e., rendezvous, capture, on-orbit maintenance, redeployment, reboost and earth return.

6.2 Equipment Reliability

The HST and SSE shall meet the requirement that no single failure or operator error result in damage to the Space Shuttle. Any deployment or extension which could prevent payload bay door closure must be controlled by independent primary and backup methods, and the combination must be two-failure tolerant. Payload equipment which could interfere with the closing of the payload bay doors shall be jettisonable without EVA.

The HST shall have no single point failure that will jeopardize recovery of the HST or affect Space Shuttle crew safety. Nor shall a single point failure within the HST subsystems cause a permanent loss of command capability, engineering telemetry, or scientific data. HST structures shall be designed with adequate factors of safety to meet these requirements.

1. NUMBER	2. PCN	SPACE TELESCOPE CRITICAL DECISION ISSUE	3. DATE	4. PAGE
049	AN3448		3/17/88	1 of 6

5. TO:	6. THRU:	7. FROM:
TA01/F. S. Wojtalik	TA51/M. Rosenthal	TA51/E. Clark

8. NAME OF ISSUE: Deletion of Requirement for Contingency Earth Return on Maintenance Missions

9. BASELINE DOCUMENTATION AFFECTED:
Hubble Space Telescope Level I Requirements (See Attachment 1)

10. DESCRIPTION OF ISSUE:

Current requirements provide for the contingency return of the HST on a maintenance mission. The HST servicing workshop at GSFC in 1987 resulted in a recommendation that HST contingency return be deleted for all maintenance missions.

This recommendation was incorporated in a draft of a new HST operations Level 1 Requirements document which is in a study/review stage at this time.

Deleting the contingency for ground return of the HST on a maintenance mission is recommended for the following reasons:

1. Makes available approximately 500 lbs of OMS fuel that would be required to deorbit the HST.

   a. This additional OMS allows for contingencies in initial rendezvous, and re-rendezvous following redeployment.

   b. Provides approximately five more miles of reboost capability.

2. Simplifies mission planning and ensures that all STS capability available for the maintenance mission activities can be effectively utilized.

3. Could save approximately 1500 lbs in trunnion hardware.

11. FOR INFORMATION ONLY ☐	LEVEL I RESERVE ALLOCATION REQUESTED: ☐
TECHNICAL APPROVAL REQUESTED ☒	FUNDING REQUIRED: $
	COST CODE:

12. SIGNATURE OF ORIGINATOR:	DATE:	TELEPHONE:	OFFICE SYMBOL:
E. Clark	3-17-88	8-824-0685	TA-51

13. CONCURRENCE

INITIAL MANAGEMENT OFFICIAL:	DATE:	SCREENING OFFICIAL:	DATE:
Mary Rosenthal	3-17-88		4-3-89

14. APPROVAL

ST PROJECT MANAGER:	DATE:	LEVEL I ☐	ST DEVELOPMENT DIVISION DIRECTOR:	DATE:
Fred S Wojtalik	1/4/89		Approved with modifications	8/25/89

15. DECISION PACKAGE AVAILABILITY DATE:	16. HEADQUARTERS DECISION REQUIRED BY:

TA-5RR1-2/84 (OT)

10. Description of Issue (Cont'd.):

4. Ground refurbishment of HST has been deleted and return of the HST to the ground would not be a cost effective option.

5. Deletion of ground return on a maintenance mission would still allow for a planned return at the end of life if required for safety (uncontrolled re-entry).

Request approval of this CDI to allow the HST Level I requirements to be changed as shown in Attachment 2.

NOTE: Change to paragraph 2.2.1 of Level I Requirements also includes editorial changes to clarity methods to maximize HST operational lifetime.

New Level I Reqs Spec takes precedence.

5/25/93

— Now Level I specific spec takes precedence.

ATTACHMENT 1

5/25/89

IS:

2.2 MISSION REQUIREMENTS

2.1 Inflight Transportation

The HST shall be delivered to orbit by the Space Shuttle transportation system with a capability for contingency return to earth on the inital deployment mission. The Space Shuttle transportation and retrieval system shall be utilized to deliver HST SSE and trained EVA crewpersons for on-orbit maintenance of HST.

2.2 Operational Life

The lifetime of the Hubble Space Telescope is expected to exceed a decade. To fullfill a broad range of scientific requirements over its lifetime the HST shall be designed for on-orbit replacement of scientific instruments (SIs) as well as other support system Orbital Replaceable Units (ORUs). The HST shall be designed to permit on-orbit retrieval, reboost and redeployment utilizing the Space Shuttle.

2.2.1 Fifteen Year On-Orbit Operational Goal

The goal for the operational life of the HST shall be fifteen years. Orbital maintenance and operational work-arounds are the tools available to extend the life of the HST toward this fifteen year goal.

WAS:

2.0 MISSION REQUIREMENTS

2.1 Inflight Transportation

The ST shall be delivered to orbit and returned to earth by the Space Shuttle transportation and retrieval system. The Space Shuttle transportation and retrieval system shall be utilized to deliver HST SSE and trained EVA crewpersons for on-orbit maintenance of HST.

2.2 Operational Life

The lifetime of the Hubble Space Telescope is expected to exceed a decade. To allow updating of the scientific instruments (SI) and the use of the ST to fullfill a broad range of scientific requirements over its lifetime, the ST shall be designed to permit on-orbit maintenance and repair, reboost, and be retrievable by the Space Shuttle for return to earth as a contingency in the event the HST cannot be maintained in orbit.

2.2.1 Fifteen Year on-Orbit Operational Goal

The goal for on-orbit operational life shall be fifteen years before ground return is planned. This fifteen year goal shall be achieved through on-orbit maintenance missions.

To be re-checked in light of issued Level 1 HST Operations Doc.

9/25/89

OTHER DOCUMENTS

ICD-A-14009-MM	1.2.1.1, 1.2.1.3, FIG. E3.1.1.2-1 (sheet 1), Fig. U3.1.2-1 (sheet 1), E3.3.1.1, E3.3.1.2.2, E3.3.1.2.2.1, E3.3.1.2.2.2, E3.3.1.3.1, E3.5.1, E3.5.1.1, E3.5.5, E3.4.1.a, Table U7.1.1-1, Fig. U7.1.1-2, E10.7.4.3.3.5
HST ICD-29	3.2.2
STS/ST PIP:JSC 14009B	1.0, 3.0, 3.2, 4.1.3, 4.1.4, 5.1.a, 5.1.c, 5.1.d, 5.4, 6.1, 8.3, 11.0, Table 13-1, Fig. 13-2.
SMR-1000	1.1, 1.4
MSFC-RQMT-691.2B	3.1.e, 3.2.1.4, 3.2.2.1, 3.2.2.2.1, 3.2.2.2.6, 3.2.2.2.9, 3.2.2.2.11, 3.3.1.8.b, 3.3.2.5, 3.3.3, Fig. A-7
-691.3	3.1.2, Fig. 9, Fig. 10, 4.1
-691.4A	1.1.1, 3.2
-691.7	1.3.5, 1.3.15, 1.4.1, 1.4.2, 1.4.5
HST CEI STE-01C	3.1.1.b, 3.1.3.3, 3.2.1.2.d, 3.3.2.1.4
-02D	3.2.4.2, 3.3.2.1
-03D	3.2.1.1.c, 3.2.1.2.e, 3.2.4.2, 3.3.2.1.4
-05	3.3.8.2
-07	3.3.8.2
-08	3.3.8.2
-12D	3.1.3.e, 3.2.1.2.3.j, 3.2.1.3.2,b.4
HST ICD ICD-01F	3.6.1.4.2.5
-02E	3.6.1.3
-03F	3.6.1.3
-10D	3.2.2, 4.1, 4.1.3, 4.2.5, 4.2.6, 4.4.8; Tables 7.0-1, 7.1-5, 7.1-6, 7.2-2, 7.2-3; 4.5.3.4, 6.1.1.2, 7.1.8

BASELINED DOCUMENT AFFECTED

MM Annex 1 (PIP) (LMSC/FO61880A)	1.3.c.6, 2.1.5, Table 1-6, Table 1-7, Fig. 1-9, Fig. 1-10, Fig. 1-11, Fig. 2-4, 4.1
MM Annex 2 (PIP)	No impact
MM Annex 3 (PIP) (LMSC/FO61863A)	2.1; Table 3-1, (#3.4.8, #3.4.10.1); 4.5, Table 4-3, Fig. 6-9, Fig. 6-10, Fig. 6-11
MM Annex 4 (PIP)	No impact
MM Annex 5 (PIP)	No impact
MM Annex 6 (PIP) (LMSC/FO61884A)	Table 3-3, page 4
MM Annex 7 (PIP)	No impact
MM Annex 11 (PIP) (LMSC/FO61888A)	1.c, 1.3, 2.2.1.2.d, 2.2.10, 2.3.2, 3.34.2.a.1

1. NUMBER	2. PCN	SPACE TELESCOPE CRITICAL DECISION ISSUE	3. DATE	4. PAGE
053	AN3775		1 Nov 89	1 of 1

5. TO:	6. THRU:	7. FROM:
TA01/Fred S. Wojtalik	EB12/J. L. Miller	EB14/A. Davis

8. NAME OF ISSUE:

Rewrite Level I Requirements, Electrical Power System

9. BASELINE DOCUMENTATION AFFECTED:

Level I Requirements fro Operational Phase of the HST Program, 17 May 89

10. DESCRIPTION OF ISSUE:

In response to HST FRR RID E-1008 and resulting Pre-Board action, MSFC ECR EB14-0648 was submitted to change Para. 3.3.1, Power, as follows:

Page 3, Para. 3.3.1, Power, CHANGE:

FROM: The power system shall provide 4400 watts at 32 volts outside of eclipse at the battery bus, two years after initiation of on-orbit operations; 550 watts shall be available at any orbital phase for operation of the Science Instruments and the SI C&DH, and for operation in the parallel science mode. Battery conditioning or recharging shall function and be managed to preserve at least 20 minutes of dark time per orbit, averaged over the precession cycle, for the conduct of scientific observations.

TO: The electrical power system shall provide adequate energy to maintain the scientific operational capabilities stated in Para. 3.2 and 3.2.1. In addition, the batteries shall maintain sufficient storage capability to enter safemode or gravity gradient mode (164 AH). A maintenance mission will be required when the battery storage capability is projected to be less than 164 AH within the next six months or when the solar array capability is projected to be less than that required to maintain the scientific operational capabilities stated in Para. 3.2 and 3.2.1 throughout the upcoming six months.

11. FOR INFORMATION ONLY ☐	LEVEL I RESERVE ALLOCATION REQUESTED: ☐
TECHNICAL APPROVAL REQUESTED ■	FUNDING REQUIRED: $
	COST CODE:

12. SIGNATURE OF ORIGINATOR:	DATE:	TELEPHONE:	OFFICE SYMBOL:
W. A. Davis W. A. Davis	11/3/89	544-3391	EB14

13. CONCURRENCE

INITIAL MANAGEMENT OFFICIAL:	DATE:	SCREENING OFFICIAL:	DATE:
R. Lanier MSFC/EB12	11/6/89	J. L. Miller MSFC/EB11	6 Nov '89

14. APPROVAL

ST PROJECT MANAGER:	DATE:	LEVEL I	ST DEVELOPMENT DIVISION DIRECTOR:	DATE:
Fred S. Wojtalik	11/27/89	■		2-9-90

15. DECISION PACKAGE AVAILABILITY DATE:	16. HEADQUARTERS DECISION REQUIRED BY:

TA-58R1-3/84 (OT)

1. NUMBER	2. PCN	SPACE TELESCOPE CRITICAL DECISION ISSUE	3. DATE	4. PAGE
054	AN3773		28 Nov 89	1 of 1

5. TO:	6. THRU:	7. FROM:
TA01/Fred Wojtalik	EJ31/W. Taylor	EL52/G. Ritter

8. NAME OF ISSUE:

HST Level I 15-Year Maintainability Requirement

9. BASELINE DOCUMENTATION AFFECTED:

HST Level I Requirements for Operational Phase

10. DESCRIPTION OF ISSUE:

A 15-year operational life of the HST cannot be assured through on-orbit maintenance. The HST design and configuration does not permit the on-orbit replacement of ALL equipment that could fail during the life of the HST. Accordingly, the Level I Requirements for the Operational Phase require modification as follows:

Page 1, Para. 2.1, Operational Life, CHANGE TO READ:

A high level of scientific productivity, using acquisition methods and strategies in conjunction with instrumentation selected through peer review, shall be maintained *to the extent possible and/or practical for a period of 15 years or longer.* The measures to be taken to achieve this will include:

(Ref: HST FRR RID M-1002)

11. FOR INFORMATION ONLY	☐	LEVEL I RESERVE ALLOCATION REQUESTED:	☐
TECHNICAL APPROVAL REQUESTED	■	FUNDING REQUIRED:	$
		COST CODE:	

12. SIGNATURE OF ORIGINATOR:	DATE:	TELEPHONE:	ORG/SPACE SYMBOL:
Glen D. Ritter Glen D. Ritter	11/29/89	544-2288	EL52

13. CONCURRENCE

INITIAL MANAGEMENT OFFICIAL:	DATE:	SCREENING OFFICIAL:	DATE:
Don Woodruff EL51/L. Don Woodruff	11/29/89	Chapman Baltuttis EJ31/W. E. Taylor	1/30/89

14. APPROVAL

ST PROJECT MANAGER:	DATE:	LEVEL I	ST DEVELOPMENT DIVISION DIRECTOR:	DATE:
		■		2/8/90

15. DECISION PACKAGE AVAILABILITY DATE:	16. HEADQUARTERS DECISION REQUIRED BY:

TA-58R1-3/84 (OT)

TF

1. NUMBER	2. PCN	SPACE TELESCOPE CRITICAL DECISION ISSUE	3. DATE	4. PAGE
055	AN3828		30 Nov 89	1 of 1

5. TO:	6. THRU:	7. FROM:
TA01/Fred S. Wojtalik	EJ31/W. Taylor	EB21/C. Jones

8. NAME OF ISSUE:

Straylight Performance (Scattered Light Surface Brightness)

9. BASELINE DOCUMENTATION AFFECTED:

HST Level I Requirements, 23 December 83

10. DESCRIPTION OF ISSUE:

HST FRR RID O-1002 addressed the inability of the HST spacecraft to meet the established Level I scattered light requirements. The scattered light surface brightness of less than 23Mv per square seconds of arc will not be met within 90° of arc of the bright earth limb due to dust. As a result, the HST Science Institute was requested to identify the impact to the science operations so that Perkin-Elmer could develop the necessary waiver. This action has been accomplished and P-E submitted DAR 062 against STE-02, OTA CEI Specification; however, the Level I requirements will have to be modified to reflect the deviation to scattered light surface brightness. Accordingly, it is requested that the following change be approved and incorporated by NASA Headquarters:

Page 4, Para. 3.1.7, Stray-Light Performance, CHANGE:

From: The scattered light surface brightness .... or 80 degrees of arc of the bright earth limb.

To: The scattered light surface brightness .... or 90 degrees minimum of arc of the bright earth limb.

(Ref: HST FRR RID O-1002/P-E DAR 062)

11. FOR INFORMATION ONLY ☐	LEVEL I RESERVE ALLOCATION REQUESTED: ☐
TECHNICAL APPROVAL REQUESTED ■	FUNDING REQUIRED: $
	COST CODE:

12. SIGNATURE OF ORIGINATOR:	DATE:	TELEPHONE:	OFFICE SYMBOL:
W. E. Taylor for C. O. Jones	12/11/89	544-3433	EB21

13. CONCURRENCE

INITIAL MANAGEMENT OFFICIAL	DATE:	SCREENING OFFICIAL:	DATE:
W. E. Taylor	12/11/89		1-12-90

14. APPROVAL

ST PROJECT MANAGER:	DATE:	LEVEL I	ST DEVELOPMENT DIVISION DIRECTOR:	DATE:
Fred S. Wojtalik	12/11/89	■		1-12-90

15. DECISION PACKAGE AVAILABILITY DATE:	16. HEADQUARTERS DECISION REQUIRED BY:

TA-58R1-3/84 (OT)

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HST-057	AN3829		9/20/89	1 OF 3

TO	THRU	FROM
TA01/Fred S. Wojtalik	James V. Moore	David R. Skillman

NAME OF ISSUE

CLARIFICATION OF TARGET ACQUISITION ACCURACY

BASELINE DOCUMENTATION AFFECTED

1983 LEVEL I RQMTS 3.1.5 & 1989 OPNL LEVEL I RQMTS 3.1.2

DESCRIPTION OF ISSUE

The Level I requirements specify the ability of HST to position, in any instrument aperture, a target to an accuracy of 0.01 arcseconds (0.03 arcseconds for the 1989 document). The ability of the HST to meet this requirement needs to be clarified since there are many different ways in which HST "pointing" is accomplished.

The Level I spec will be met in the following situations:

a. A revisit to the same target using the same guide stars,

b. An offset from one part of the HST field-of-view to another, as long as guide stars are not lost.

The Level I spec will not be met in the following situations:

c. The ability of HST to "point" to an absolute position (precise coordinates on the sky) is limited to the accuracy of the guide stars. This accuracy is of the order of one or two arcseconds.

d. If a real-time interaction with the ground system is used to aid pointing, the accuracy to which a target can be positioned (in that SI) is limited to the centering capabilities of the ground algorithm convolved with the effective pixel size of that SI, typically ranging from 0.5 arcseconds to 0.043 arcsec

LEVEL I RESERVE ALLOCATION REQUESTED ☐	FUNDING REQUIRED $	COST CODE

SIGNATURE OF ORIGINATOR	DATE	TELEPHONE	OFFICE SYMBOL
David R. Skillman			440

CONCURRENCE

INITIAL MANAGEMENT OFFICIAL	DATE	SCREENING OFFICIAL	DATE
/s/ James V. Moore			

MSFC LEVEL II DISPOSITION

PROJECT MANAGER	DATE		
Fred S. Wojtalik	12/11/89	■ APPROVED	■ LEVEL I DISPOSITION REQUIRED
HEADQUARTERS DECISION REQUIRED BY		☐ DISAPPROVED	
		☐ FORWARDED FOR INFO ONLY	☐ LEVEL II ONLY

NASA HQ DISPOSITION

PROGRAM MANAGER	DATE		DECISION PACKAGE AVAILABILITY DATE
	1-12-90	☑ APPROVED	
		☐ DISAPPROVED	

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NAME OF ISSUE

CLARIFICATION OF TARGET ACQUISITION ACCURACY

DESCRIPTION OF ISSUE

e. If an SI is used to autocenter, the accuracy to which a target can be positioned (in that SI) is limited to the autocentering capabilities of that SI, typically ranging from 0.5 arcseconds to 0.022 arcseconds.

f. If one SI is used to assist the acquisition of the target in a second SI (as in WF/PC assisted target acquisitions), the positioning accuracy is limited to the accuracy of the first SI. Even this accuracy may be degraded since the same guide star pair typcially cannot be shared by the two SIs.

FROM: (Rec. Lev 1 Spec dated May 17, 1985) 1-12-90

3.1.2 Target Positioning

The HST shall acquire and position a fixed or moving target within any of the instrument apertures with an error no greater than 0.03 arcsec.

TO:

3.1.2 The HST shall contribute an error no greater than 0.03 arcseconds during the acquisition and positioning of a fixed or moving target within any instrument aperture.

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CLARIFICATION OF TARGET ACQUISITION ACCURACY

DESCRIPTION OF ISSUE

PLANNED IMPLEMENTATION SCHEDULE:

Capability / Delivery	Moving Targets
F1 (Oct 15,90)	Complex 1.2 Single GS pair Ops
	Complex 1.3 Multiple GS pair ops
F2 (Mar 1.91)	Complex 2 - 20 mas ops - RT motion mod - extended track

REVISED IN ACCORDANCE TO HQ LTR., 3/4/90

NUMBER	PCN	SPACE TELESCOPE CRITICAL DECISION ISSUE	DATE	PAGE
HST-058R1	AN3830		3/27/90	1 OF 2

TO	THRU	FROM
TA01/Fred S. Wojtalik	James V. Moore	David R. Skillman

NAME OF ISSUE

GUIDE STAR ACQUISITION PROBABILITIES

BASELINE DOCUMENTATION AFFECTED

1983 LEVEL I RQMTS, 3.1.6 & 1989 OPNL LEVEL I RQMTS, 3.1.3

DESCRIPTION OF ISSUE

Section 3.1.6 of the 1983 Level I requirements document describes the Guide Star Acquisition requirements that have been used to develop both the HST flight hardware and the ground system operational procedures.

Section 3.1.3 of the 1989 Level I requirements document attempts to restate this requirement. It does not succeed and creates ambiguities.

The HST Program requests the replacement of 1989 section 3.1.3 by the wording of 1983 section 3.1.6 but retaining the 75% criterion.

In the 1989 Level I document:

WAS prior to this CDI:

3.1.3 Guide Star Acquisition and Tacking

In order to meet the requirements in Section 3.1.1 and 3.1.2, the HST shall be capable of acquiring and achieving fine lock on stars as faint as Mv=14.5 with two fully functional Fine Guidance Sensor systems. Equivalently, for three operational Fine Guidance Sensor systems, the HST shall acquire and achieve fine lock for at least 75% of randomly selected targets.

Continued on next page

LEVEL I RESERVE ALLOCATION REQUESTED ☐	FUNDING REQUIRED $	COST CODE

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CONCURRENCE

INITIAL MANAGEMENT OFFICIAL	DATE	SCREENING OFFICIAL	DATE
/s/ James V. Moore			

MSFC LEVEL II DISPOSITION

PROJECT MANAGER	DATE		
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HEADQUARTERS DECISION REQUIRED BY		☐ DISAPPROVED	☐ LEVEL II ONLY
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NASA HQ DISPOSITION

PROGRAM MANAGER	DATE		DECISION PACKAGE AVAILABILITY DATE
	4-18-90	■ APPROVED	
		☐ DISAPPROVED	

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NAME OF ISSUE

GUIDE STAR ACQUISITION PROBABILITIES

DESCRIPTION OF ISSUE

IS now requested to read:

3.1.3 Guide Star Acquisition and Tracking

The HST must be able to acquire and track on guide stars in at least 75% of randomly selected targets located at the galactic poles when using the stellar statistics of "Guide Star Probabilities", NASA Contractor Report 3374, January 1981.

Initial Submittal

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TO	THRU	FROM
TA01/Fred S. Wojtalik	James V. Moore	David R. Skillman

NAME OF ISSUE

GUIDE STAR ACQUISITION PROBABILITIES

BASELINE DOCUMENTATION AFFECTED

1983 LEVEL I RQMTS, 3.1.6 & 1989 OPNL LEVEL I RQMTS, 3.1.3

DESCRIPTION OF ISSUE

Section 3.1.6 of the 1983 Level I requirements document describes the Guide Star Acquisition requirements that have been used to develop both the HST flight hardware and the ground system operational procedures.

Section 3.1.3 of the 1989 Level I requirements document attempts to restate this requirement. It does not succeed and creates ambiguities.

The HST Program requests the replacement of 1989 section 3.1.3 by the identical wording of 1983 section 3.1.6.

LEVEL I RESERVE ALLOCATION REQUESTED ☐	FUNDING REQUIRED $	COST CODE

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CONCURRENCE

INITIAL MANAGEMENT OFFICIAL	DATE	SCREENING OFFICIAL	DATE
/s/ James V. Moore			

MSFC LEVEL II DISPOSITION

PROJECT MANAGER	DATE		
Fred S. Wojtalik	12/11/89	■ APPROVED	■ LEVEL I DISPOSITION REQUIRED
HEADQUARTERS DECISION REQUIRED BY		☐ DISAPPROVED	
		☐ FORWARDED FOR INFO ONLY	☐ LEVEL II ONLY

NASA HQ DISPOSITION

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		☐ DISAPPROVED	

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HST-059	AN3831		9/20/89	1 OF 3

TO	THRU	FROM
TA01/Fred S. Wojtalik	James V. Moore	David R. Skillman

NAME OF ISSUE

PARALLEL SCIENCE CAPABILITY WAIVER (SCHEDULE)

BASELINE DOCUMENTATION AFFECTED

1983 LEVEL I RQMTS 3.3 & 1989 OPNL LEVEL I RQMTS 4.2.2

DESCRIPTION OF ISSUE

The full parallel science capability described in the Level I requirements document cannot be met for a 3/90 launch. (See implementation schedule on page 3).

The HST Program requests a waiver of this requirement for the launch time frame. These capabilities are under development and will be attained by a phased set of software builds and deliveries, with increasing capabilities culminating to meet the full requirement on a schedule which is attached. A brief description follows:

Phase I Parallel Science

- Simultaneous readouts from SIs operating at low (less than 40 Kbs) rates. This is accomplished via utilizing the onboard data interleaving capabilities of the flight hardware and by limiting the aggregate data rate to less than 32 Kbs. Data will go into the flight tape recorders at the 32 Kbs rate.

Phase 2 Parallel Science

- Parallel WF/PC readouts will be available during those intervals when the prime SI is not transferring data (non-interference mode). If the prime SI does not leave sufficient time for a WF/PC readout, no WF/PC parallel activities can be allowed.

LEVEL I RESERVE ALLOCATION REQUESTED ☐	FUNDING REQUIRED $	COST CODE

SIGNATURE OF ORIGINATOR	DATE	TELEPHONE	OFFICE SYMBOL
David R. Skillman			440

CONCURRENCE

INITIAL MANAGEMENT OFFICIAL	DATE	SCREENING OFFICIAL	DATE
/s/ James V. Moore			

MSFC LEVEL II DISPOSITION

PROJECT MANAGER	DATE		
Fred S. Wojtalik	12/15/89	■ APPROVED	■ LEVEL I DISPOSITION REQUIRED
HEADQUARTERS DECISION REQUIRED BY		☐ DISAPPROVED	☐ LEVEL II ONLY
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NASA HQ DISPOSITION

PROGRAM MANAGER	DATE		DECISION PACKAGE AVAILABILITY DATE
Requirements Engineering Branch	1-12-90	☒ APPROVED	
		☐ DISAPPROVED	

NUMBER	PCN	SPACE TELESCOPE CRITICAL DECISION ISSUE (CONTINUATION SHEET)	DATE	PAGE
HST-059	AN3831		9/20/89	2 OF 3

NAME OF ISSUE

PARALLEL SCIENCE CAPABILITY WAIVER (SCHEDULE)

DESCRIPTION OF ISSUE

Phase 2 Parallel Science (Continued):

- Major software additions must be made to the planning and scheduling systems.

Phase 3 Parallel Science

- Full WF/PC interleavability with any prime SI with minimal interference. This is accomplished by developing methods of operating the other SIs that allow momentary suspension of data flows. Tape recorder speed changes (needed to allow WF/PC transfers) can then be accommodated without major disruptions to the prime SI.

- Software and procedural changes must be developed together to achieve this capability.

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HST-059	AN3831		9/20/89	3 OF 3

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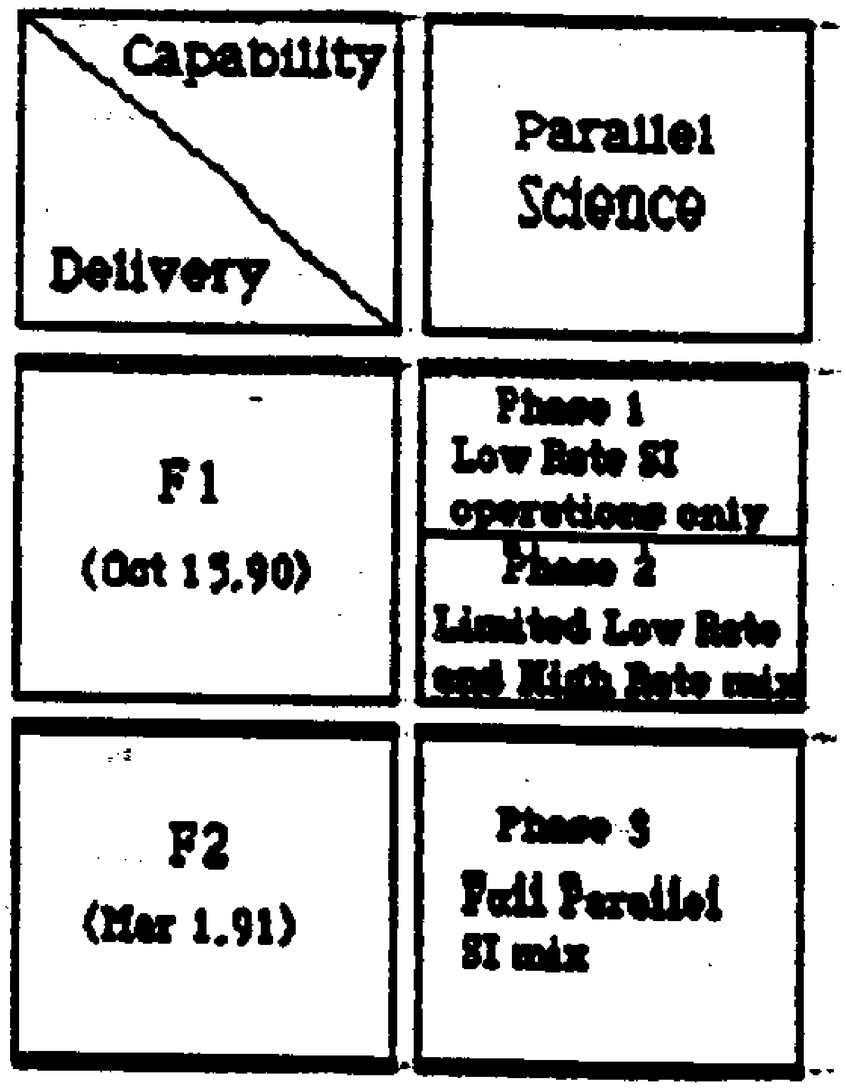
PARALLEL SCIENCE CAPABILITY WAIVER (SCHEDULE)

DESCRIPTION OF ISSUE

PLANNED IMPLEMENTATION SCHEDULE:



REVISED IN ACCORDANCE WITH HQ LTR., 3/4/90

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HST-061R1	AN3833		3/27/90	1 OF 2

TO	THRU	FROM
TA01/Fred S. Wojtalik	James V. Moore	David R. Skillman

NAME OF ISSUE

CLARIFICATION OF PLANNING AND SCHEDULING EFFICIENCY

BASELINE DOCUMENTATION AFFECTED

1989 OPERATIONAL LEVEL I REQUIREMENTS

DESCRIPTION OF ISSUE

Reference Section 4.2.2a and 4.2.2e.

There are three related issues in this area:

1) Section 4.2.2a calls out a goal of 35% "efficiency" in the operation of HST.

   - The HST program accepts this goal but notes that the initial efficiencies are expected to be in the 15% to 20% range until experience accumulates and the HST enters into more routine operations.

2) Section 4.2.2e calls out a 2:1 schedule generating capability that allows schedules for a given interval to be produced in half of the length of that time interval (i.e. a 12 hour schedule should be able to be generated in 6 hours or less).

   - The current ground system can produce schedules slightly faster that 1:1, but cannot yet meet the 2:1 requirement. The production rates should improve as experience is obtained, but the HST program can only accept this requirement as a goal given the current hardware, software, and resources situation.

3) Section 4.2.2e also calls out a requirement to be able to reschedule 25% of the "activities". (Continued on next page)

LEVEL I RESERVE ALLOCATION REQUESTED ☐	FUNDING REQUIRED $	COST CODE

SIGNATURE OF ORIGINATOR	DATE	TELEPHONE	OFFICE SYMBOL
David R. Skillman			440

CONCURRENCE

INITIAL MANAGEMENT OFFICIAL	DATE	SCREENING OFFICIAL	DATE
/s/ James V. Moore			

MSFC LEVEL II DISPOSITION

PROJECT MANAGER	DATE		
Fred S. Wojtalik	3/29/90	■ APPROVED ☐ DISAPPROVED ☐ FORWARDED FOR INFO ONLY	■ LEVEL I DISPOSITION REQUIRED ☐ LEVEL II ONLY
HEADQUARTERS DECISION REQUIRED BY			

NASA HQ DISPOSITION

PROGRAM MANAGER	DATE		DECISION PACKAGE AVAILABILITY DATE
	4-18-90	■ APPROVED ☐ DISAPPROVED	

NUMBER	PCN	SPACE TELESCOPE CRITICAL DECISION ISSUE (CONTINUATION SHEET)	DATE	PAGE
HST-061R1	AN3833		3/27/90	2 OF 2

NAME OF ISSUE

CLARIFICATION OF PLANNING AND SCHEDULING EFFICIENCY

DESCRIPTION OF ISSUE

- A requirement is already carried on the internal acceptability of SMSs (SE-06-1 sec. 3.2.2.3). This requirement calls out that 5% or less of the SMSs will be rejected due to internal defects, so that only 5% will need rework. If external factors, such as TDRSS rejections, cause observations to be rejected for considerations beyond the control of the ground system (externally defective), major inefficiencies will result. These external defects could contaminate every SMSs and create a repair job that would easily swamp the current ground system.

  Thus if this Level I requirement addresses the case of 25% of SMSs being externally defective, the ground system would be stressed but could handle it. If the intent is that 25% of observations are externally defective, then every SMS will be defective and will require rework. The as-built ground system cannot meet this second scenario. The as-built ground system accepts a 5% (of SMSs) replan effort but cannot accept a rework of 25% of observations.

Change language request to 1989 Operational Level I requirement 4.2.2e:

WAS prior to this CDI:

e. Preparation of schedules and command loads for 24 clock-time hours of HST operation, including scheduling of parallel activities in less than 12 working hours, and including the ability to reschedule 25% of these activities in response to mission needs.

IS now requested to read:

e. Preparation of schedules and commands loads for 24 clock-time hours of HST operation, including scheduling of parallel activities in less than 12 working hours as a goal, and including the ability to reschedule 5% of these activities in response to mission needs.

INITIAL SUBMITTAL

1. NUMBER	2. PCN	SPACE TELESCOPE CRITICAL DECISION ISSUE	3. DATE	4. PAGE
061 (GSFC L1-6)	AN3833		9/22/89	1

5. TO:	6. FROM:	7. PHONE
Fred S. Wojtalik	James V. Moore	David R. Skillman

8. NAME OF ISSUE:

Clarification of Planning and Scheduling Efficiency

9. BASELINE DOCUMENTATION AFFECTED:

1989 Operational Level 1 Requirements, sec. 4.2.2a, 4.2.2e

10. DESCRIPTION OF ISSUE:

1) Section 4.2.2a calls out a goal of 35% "efficiency" in the operation of HST.

- The HST program accepts this goal but notes that the initial efficiencies are expected to be in the 15% to 20% range until experience accumulates and the HST enters into more routine operations.

2) Section 4.2.2e calls out a 2:1 schedule generating capability that allows schedules for a given interval to be produced in half of the length of that time interval (i.e. a 12 hour schedule should be able to be generated in 6 hours or less).

- The current ground system can produce schedules slightly faster than 1:1, but cannot yet meet the 2:1 requirement. The production rates should improve as experience is obtained, but the HST program can only accept this requirement as a goal given the current hardware, software, and resources situation.

3) Section 4.2.2e also calls out a requirement to be able to reschedule 25% of the "activities." A clarification is needed if this requirement is to be retained as is.

(see the attached sheet for continuation)

11. FOR INFORMATION ONLY ☐		LEVEL I RESERVE ALLOCATION REQUESTED: ☐	
TECHNICAL APPROVAL REQUESTED ■		FUNDING REQUIRED: $	
		COST CODE:	
12. SIGNATURE OF ORIGINATOR: David R. Skillman	DATE:	TELEPHONE:	OFFICE SYMBOL: 440

12. CONCURRENCE

INITIAL MANAGEMENT OFFICIAL:	DATE:	SCREENING OFFICIAL:	DATE:
/s/ James V. Moore	12/7/89		

14. APPROVAL

ST PROJECT MANAGER:	DATE:	LEVEL I	ST LEVEL/SUPPORT DIVISION DIRECTOR:	DATE:
Fred S. Wojtalik	12/11/89	■		

15. DECISION PACKAGE AVAILABILITY DATE:

Continued (Clarification of Planning and Scheduling Efficiency)

- A requirement is already carried on the internal acceptability of SMSs (SE-06-1 sec. 3.2.2.3). This requirement calls out that 5% or less of the SMSs will be rejected due to internal defects, so that only 5% will need rework. If external factors, such as TDRSS rejections, cause observations to be rejected for considerations beyond the control of the ground system (externally defective), major inefficiencies will result. These external defects could contaminate every SMSs and create a repair job that would easily swamp the current ground system. Thus if this Level I requirement addresses the case of 25% of SMSs being externally defective, the ground system would be stressed but could handle it. If the intent is that 25% of observations are externally defective, than every SMS will be defective and will require rework. The as-built ground system cannot meet this second scenario. The as-built ground system accepts a 5% (of SMSs) replan effort but cannot accept a rework of 25% of observations.

To modify the ground system to meet the second scenario would require a large investment of manpower, time, and budget resources. There is no indication that problems requiring a 25% rescheduling of activities exists. If such a problem were to materialize after launch, there already exists workarounds that would preserve most of the science efficiency. At that time sufficient information about HST system performance would be available to design an appropriate enhancement to the ground system.

1. NUMBER: 062 (GSFC L1-7)	2. PCR: AN3834	SPACE TELESCOPE CRITICAL DECISION ISSUE	3. DATE: 9/22/89	4. PAGE: 1
5. TO: Fred S. Wojtalik	6. FROM: James V. Moore	7. FROM: David R. Skillman		

8. NAME OF ISSUE:
Branching

9. BASELINE DOCUMENTATION AFFECTED: 1983 Level 1 Requirements, sec. 7.3 and 1989 Operational Level 1 Requirements, sec. 4.2.1b

10. DESCRIPTION OF ISSUE:

The HST ground system does not support this requirement. There is no current plan to achieve this capability. The HST program requests a deferral of this requirement.

The ability to execute a "branch" (an alternate path of instrument operations) requires separate command sequences to be resident in the HST for each possible path of the "branch". Such alternate command paths are lengthy (require many commands) because of the complexity of operating HST. Each path may have different needs for the tape recorder, downlink, data rate, pointing, avoidance angles, etc.

A study is underway by the HST Science Working Group (SWG) to define a limited envelope of choices that would allow useful but highly simplified branching to be achieved. A set of constraints that limit branches to those with almost identical on-board resource requirements is needed before branching can be accomplished.

Change language request to 1989 Operational Level I requirement 4.2.1b:

From:

b. Interactive selection and execution of alternative preplanned mission sequences (referred to as branching) for up to 20% of the total activity.

To:

b. Deferred.

Intent Approved. Specific wording change disapproved. See cover letter for comments. 1-12-90

11. FOR INFORMATION ONLY: ☐	LEVEL I REVIEW/ALARM REQUESTED: ☐
TECHNICAL APPROVAL REQUESTED: ☒	FUNDING REQUIRED: $
	COST CODE:

12. SIGNATURE OF ORIGINATOR: David R. Skillman	DATE:	TELEPHONE:	OFFICE SYMBOL: 440

12. CONCURRENCE

INITIAL MANAGEMENT OFFICIAL: /s/ James V. Moore	DATE: 12/7/89	INTERFACE OFFICIAL:	DATE:

14. APPROVAL

ST PROJECT MANAGER: Fred S. Wojtalik	DATE: 12/11/89	LEVEL I: ☒	OFFICE OF DEVELOPMENT DIRECTOR: with modifications	DATE: 1-12-90

15. DECISION PACKAGE AVAILABILITY DATE:

16. HEADQUARTERS DECISION RECEIVED BY:

NUMBER	PCN	SPACE TELESCOPE CRITICAL DECISION ISSUE	DATE	PAGE
HST-063	AN3835		9/22/89	1 OF 3

TO	THRU	FROM
TA01/Fred S. Wotalik	James V. Moore	David R. Skillman

NAME OF ISSUE

SOLAR SYSTEM OBJECT TRACKING WAIVER (SCHEDULE)

BASELINE DOCUMENTATION AFFECTED

1989 OPNL LEVEL I RQMTS, SEC. 3.1.4 WAIVER (SCHEDULE)

DESCRIPTION OF ISSUE

The ability to point the HST to moving targets has additional complexities that require capabilities beyond those necessary to meet the fixed target pointing specification.

These additional capabilities will reside in the HST ground system. They will not be fully in place at launch. A waiver is requested that will allow these capabilities to be added incrementally to the ground system.

Guide star positions are not well enough known to allow small aperture SI to be placed accurately on a target that is either on or near a planetary disk. In order to achieve accurate placement, a WF/PC assisted acquisition is needed. The WF/PC is used to image the disk of planet and then this image is analyzed in the ground system (OSS) to determine the center of the planet. Once the planet center is known, accurate offsets may be accomplished to position the small aperture SI.

The HST ground system is being augmented to meet the Level I spec according to a schedule (attached):

LEVEL I RESERVE ALLOCATION REQUESTED ☐	FUNDING REQUIRED $	COST CODE

SIGNATURE OF ORIGINATOR	DATE	TELEPHONE	OFFICE SYMBOL
David R. Skillman			440

CONCURRENCE

INITIAL MANAGEMENT OFFICIAL	DATE	SCREENING OFFICIAL	DATE
/s/ James V. Moore			

MSFC LEVEL II DISPOSITION

PROJECT MANAGER	DATE		
Fred S. Wojtalik	12/15/89	■ APPROVED ☐ DISAPPROVED ☐ FORWARDED FOR INFO ONLY	■ LEVEL I DISPOSITION REQUIRED ☐ LEVEL II ONLY
HEADQUARTERS DECISION REQUIRED BY			

NASA HQ DISPOSITION

PROGRAM MANAGER	DATE		DECISION PACKAGE AVAILABILITY DATE
Read words Forlowski	1-12-90	☒ APPROVED ☐ DISAPPROVED	

NUMBER	PCN	SPACE TELESCOPE CRITICAL DECISION ISSUE (CONTINUATION SHEET)	DATE	PAGE
HST-063	AN3835		9/22/89	2 OF 3

NAME OF ISSUE

SOLAR SYSTEM OBJECT TRACKING WAIVER (SCHEDULE)

DESCRIPTION OF ISSUE

Launch Capablities - 0.12 arcsecond accuracy using a coarse planet center-finding algorithm and a single guide star pair.

Postlaunch Capabilities - 0.02 arcsecond accuracy using a sophisticated planet center-finding algorithm and multiple guide star pairs.

NUMBER	PCN	SPACE TELESCOPE CRITICAL DECISION ISSUE (CONTINUATION SHEET)	DATE	PAGE
HST-063	AN3835		9/22/89	3 OF 3

NAME OF ISSUE

SOLAR SYSTEM OBJECT TRACKING WAIVER (SCHEDULE)

DESCRIPTION OF ISSUE

PLANNED IMPLEMENTATION SCHEDULE:

Capability / Delivery	Moving Targets
F1 (Oct 15.90)	Complex 1.2 Single GS pair Ops
	Complex 1.3 Multiple GS pair ops
F2 (Mar 1.91)	Complex 2 • 20 mas ops • RT motion mod • extended track

1. NUMBER	2. PCR	SPACE TELESCOPE CRITICAL DECISION ISSUE	3. DATE	4. PAGE
064 (GSFC L1-9)	AN3836		11/22/89	1

5. TO:	6. FROM:	7. FROM:
Fred S. Wojtalik	James V. Moore	David R. Skillman

8. NAME OF ISSUE:

Science Data Processing and Products

9. BASELINE DOCUMENTATION AFFECTED:

1989 Operational Level 1 Requirements, sec. 4.4.3

10. DESCRIPTION OF ISSUE:

Raw edited data is not supplied to observers. Raw edited data is in a form that can only be used as the input to the calibration process. Raw edited data is in a format that makes it not displayable or reviewable by the observers.

Raw edited data is converted within 24 hours of receipt at the ST ScI into a format referred to as "uncalibrated data". This uncalibrated data is available for inspection at the ST ScI by the observer. No tape consisting only of uncalibrated data is released to the general observer unless it is from an SI mode whose calibration is not supported by the ST ScI. PIs or GTO observers who have calibration capabilities at their home institution will be provided with uncalibrated data if requested.

A tape of both uncalibrated and calibrated data is provided to the observer within 5 days of receipt at the ST ScI.

Change language request to 1989 Operational Level I requirement 4.4.3:

From:

"..........Raw edited data........"

To:

"..........Uncalibrated data in SOGS format.........."

11. FOR INFORMATION ONLY ☐	LEVEL I RESERVE ALLOCATION REQUESTED: ☐
TECHNICAL APPROVAL REQUESTED ☒	FUNDING REQUIRED: $
	COST CODE:

12. SIGNATURE OF ORIGINATOR:	DATE:	TELEPHONE:	OFFICE SYMBOL:
David R. Skillman			440

13. CONCURRENCE

INITIAL MANAGEMENT OFFICIAL:	DATE:	SECONDARY OFFICIAL:	DATE:
/s/ James V. Moore	12/7/89		

14. APPROVAL

ST PROJECT MANAGER:	DATE:	LEVEL I	BY SENIOR PROJECT DIVISION DIRECTOR:	DATE:
Fred S. Wojtalik	12/11/89	☒		1-12-90

15. DECISION PACKAGE AVAILABILITY DATE:

16. HEADQUARTERS DECISION REQUIRED BY:

NUMBER	PCN	SPACE TELESCOPE CRITICAL DECISION ISSUE	DATE	PAGE
HST-066	AN3838		12/19/89	1 OF 1

TO	THRU	FROM
TA01/Fred S. Wojtalik	James V. Moore	David R. Skillman

NAME OF ISSUE

CORE SCIENCE CAPABILITY (CLARIFICATION)

BASELINE DOCUMENTATION AFFECTED

1989 OPERATIONAL LEVEL I REQUIREMENTS, SEC. 3.2.1C

DESCRIPTION OF ISSUE

The Level I definition of a "core science capability" calls out a requirement that "in the long term, a stable observational capability shall be provided to enable near infrared spectrophotometry and imaging".

Such a capability is not available at launch, and will not be available until an IR instrument is installed in the HST during the first servicing mission (5 years post launch).

After the IR instrument exhausts it's cryogen (5 year lifetime), the remaining life of the HST mission will also lack an IR capability.

The requirement 3.2.1(c) should be clarified to read that a core science capability, enabling near infrared spectrophotometry and imaging, should be available for at least five years of the HST lifetime, and that this capability should be instituted as soon as is practical.

See cover letter for details of approval

1-12-90

LEVEL I RESERVE ALLOCATION REQUESTED ☐	FUNDING REQUIRED $	COST CODE

SIGNATURE OF ORIGINATOR	DATE	TELEPHONE	OFFICE SYMBOL
David R. Skillman			440

CONCURRENCE

INITIAL MANAGEMENT OFFICIAL	DATE	SCREENING OFFICIAL	DATE
/s/ James V. Moore			

MSFC LEVEL II DISPOSITION

PROJECT MANAGER	DATE		
Fred S. Wojtalik	12/19/89	☐ APPROVED	☐ LEVEL I DISPOSITION REQUIRED
HEADQUARTERS DECISION REQUIRED BY		☐ DISAPPROVED	
		☐ FORWARDED FOR INFO ONLY	☐ LEVEL II ONLY

NASA HQ DISPOSITION

PROGRAM MANAGER	DATE		DECISION PACKAGE AVAILABILITY DATE
Approved with Comment	1-12-90	☑ APPROVED	
		☐ DISAPPROVED	